

A HANDBOOK FOR SAFETY WITH CHEMICAL REAGENTS

by *Sue M. C.*

MERRIDY MYRTH KING

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Approved by:

Arnold J. Moore
Major Professor

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TABLE OF CONTENTS

CHAPTER	PAGE
I. THE NEED OF SAFETY	1
The Problem.	2
Statement of the problem	2
Objectives of the study.	2
Method of procedure.	2
Limitation of the study.	2
Definition of Terms.	3
Safety	3
Chemical	3
Chemical reagent	3
Physiological effect	3
Incompatible chemicals	3
Hazardous chemicals.	4
II. CONCERN'S OF CHEMICAL SAFETY	5
Fire Prevention.	5
Toxicity	6
Hazardous Chemical Reactions	6
III. PHYSIOLOGICAL EFFECTS	7
Skin Contact	7
Inhalation	8
Ingestion.	10
IV. SAFETY INSTRUCTIONS WITH CHEMICAL REAGENTS.	12
Storage.	12
Disposal	14

CHAPTER	PAGE
Chemical Reagents	18
Emergency First Aid.	34
V. SUMMARY AND CONCLUSIONS	37
BIBLIOGRAPHY	39

CHAPTER I

THE NEED OF SAFETY

Safety in the high school science laboratory has many different aspects. It is, therefore, very important that both junior high and senior high school science instructors be concerned with safety as one of their important obligations in introducing students to formal laboratory work. Safety is not only a supervisory responsibility, but also a personal responsibility; students need to be introduced to safe and proper techniques.

Safety includes prevention of accidents in the laboratory. This will perhaps have a different interpretation to the student than to the instructor; and also a somewhat different interpretation to an administrator than to either a student or an instructor. Nevertheless, all precautions should be taken to prevent any type of injury to students, damage to equipment, or damage to laboratory facilities of the building. As laboratory experiences are a fundamental part of student education, this should be accomplished in a safe laboratory environment and under the guidance of instructors who are concerned with the safety of their students.

The prevention of injuries and the maintenance of an accident-free laboratory experience are strongly dependent upon the instructor's preoccupation with a period of safety orientation prior to any actual work in the laboratory. When the student has had no previous supervised laboratory experiences, it is very important that instruction be given for even the most elementary steps in manipulation of instruments, apparatus, and glassware. Good discussion should also be given on laboratory techniques, need for correct apparatus identification and proper use of chemical reagents.

I. THE PROBLEM

Statement of the problem. The purpose of this study was to develop a handbook for safety with chemical reagents.

Objectives of the study. Safety with chemical reagents should include knowledge of the following:

1. The physiological effects of chemicals which the students may use.
2. The correct manner of storage, transport, and disposal of chemicals.
3. Types of incompatible chemicals to prevent accidental injuries.
4. Various common hazardous chemicals.

Method of procedure. The procedure used in this study consisted of the following:

1. A review of the pertinent literature contained in the Kansas State University library.
2. A review of pertinent literature as recommended by Educational Resources Information Center (ERIC).
3. An inquiry to the Science Consultant of the Kansas Department of Public Instruction.
4. A study of laboratory manuals for traditional and modern approaches to high school chemistry.
5. Preparation of a handbook for safety with chemical reagents.

Limitation of the study. Safety in the high school science laboratory includes many different aspects; such as, (1) precautions in specific

experiments, (2) proper ventilation, (3) unattended laboratory operations, (4) shielding and eye protection, (5) toxicity and exposure limits, (6) storage of chemicals, (7) disposal of chemicals, (8) lasers, (9) common accidents including cuts from glassware and burns from heat and/or chemicals, (10) handling laboratory animals, and (11) precautions for field trips as well as general safety rules for teachers and students. With such a many-faceted nature, it is impossible to treat all of these in one report. Therefore, the writer has chosen only one, that of safety with chemical reagents which are used most frequently in high schools, to be discussed in this study.

II. DEFINITION OF TERMS

Safety. This term is used in this report as any condition of being free from danger or hazard due to an accident or disease.

Chemical. This refers to any chemical element, chemical compound or to any reactant or product of a chemical reaction.

Chemical reagent. This term refers to any chemical element or chemical compound which may be used in a chemical reaction.

Physiological effects. This includes any change in the functioning of any body organ or organ system brought about in an individual by exposure to a toxic chemical element or chemical compound.

Incompatible chemicals. This group includes those chemicals which cannot be used together or stored together because of undesirable chemical reactions.

Hazardous chemicals. This group includes dangerous chemicals which cause injury to persons or damage to property as a result of their reactivity, spontaneous decomposition, instability, flammability, or volatility.

CHAPTER II

CONCERNS OF CHEMICAL SAFETY

Since the birth of chemistry, chemists have faced the problem of whether or not some chemical is harmless or very dangerous. Sometimes this problem has not been resolved soon enough and unfortunate results have occurred. This problem is not always recognized by a laboratory worker or a chemistry teacher. Chemical safety is concerned with chemicals and chemical reactions which are potentially hazardous to life or property, including fire prevention, toxicity, and hazardous chemical reactions.¹

I. FIRE PREVENTION

Fire prevention. Fire prevention includes the fundamental properties of chemical, as well as the hazardous chemical reactions which may result in fires and explosions. It is important to have knowledge of the instability of ether peroxides, and understanding of the unstable nature of alcohol-acid mixtures (as used in etching agents), and a realization of the violence of an explosion produced by the ignition of propylene-air mixtures. Fires and explosions account for the most dangerous and the most expensive laboratory accidents. A knowledge of the flammable properties of chemicals along with an understanding of potential sources of ignition is extremely vital.² Storage and handling of such materials requires special attention.

¹Howard H. Fawcett, "The Literature of Chemical Safety - Part 1," Journal of Chemical Education, XLII (October, 1965), A815.

²Peter A. Breysse, "University Program in Laboratory Management and Safety," Journal of Chemical Education, XLIII (November, 1966), A914.

II. TOXICITY

Toxicity. Toxicity should not be limited to classic poisons such as arsenic, cyanide, and lead, but to all chemicals since all have some degree of toxicity. An accurate evaluation of the hazard presented by a chemical must include information about the conditions of use, as well as the toxicity data derived from animal experiments. Effects of chemicals on skin, eyes, and other external parts of the body constitute a special class of hazards. In addition to skin reactions from strong acids and alkali, or chemicals which hydrolyze, the skin sensitization reaction may render a person extremely allergic to traces of other chemicals. The special action of many gases, dusts, mists, and vapors on the eye should be noted. Also, attention should be given to physical agents, such as ultraviolet and infrared light, as well as ionizing radiation, which affect the skin and eyes unless they are controlled adequately.

III. HAZARDOUS CHEMICAL REACTIONS

Hazardous chemical reactions. Hazardous chemical reactions include many more reactions than chemistry texts or open chemical literature may reveal. Many hazardous reactions are discovered and reported only after a highly irregular incident has occurred. Hazardous reactions may result from utilizing the raw product, or from a secondary product of a chemical reaction, or breakdown products developed through heating or aging. Despite the extreme importance of knowledge about incompatible chemicals, chemical booby-traps and hazardous chemical reactions, lists of this nature are relatively incomplete.

CHAPTER III

PHYSIOLOGICAL EFFECTS

Chemicals are the important tools of a science laboratory, but these may have unpleasant and harmful physiological effects. These toxic substances may be solids and as dust they can be wafted through the room by a slight breeze, or they may be solvents and flow downward or seep through containers, or they may be vapors which can move with the air currents in a room.

Chemicals cause harmful effects in three ways: by skin contact, by inhalation or by ingestion.¹ For some chemicals there are multiple routes of entry into the body.

I. SKIN CONTACT

Skin contact. Of the various means of body exposure to toxic agents, skin contact is the most common. Normally, the unbroken skin is an effective barrier for protection from any foreign substance due to the skin's film of lipid and sweat, preventing injury or penetration. The dust particles may react with the skin surfaces causing primary surface irritation, may be massaged into the skin coagulating tissue protein and effecting skin sensitization, or may be allowed passage through the skin by collecting in the hair follicles. This means of entry allows passage of the toxic material into the lymphatic and circulatory systems causing action as a systemic poison. Dust collecting in clothing or in leather, a very good absorber of many chemicals, can be massaged into the skin by ordinary, daily routine

¹Herbert E. Stokinger, "Means of Contact and Entry of Toxic Agents," Journal of Chemical Education, XLIV (September, 1967), A721.

activities.² Possible penetration of the skin by accidental flying objects, lacerations, or open wounds can allow a more direct entry into the body tissues.

Personal cleanliness, clothing cleanliness, and laboratory cleanliness are the best ways of avoiding the entry of chemicals by skin contact. High school instructors must impress this factor of cleanliness upon students as they are learning proper laboratory techniques and procedures.

II. INHALATION

Inhalation. Inhalation may be of particles or of gases and vapor. Air-borne substances lodge in the lungs or in other parts of the respiratory tract. Those may then pass to other internal organ systems by way of the blood, lymph, or phagocytic cells. The type and severity of the action of toxic substances depends upon such factors as the nature of the chemical, the amounts absorbed, the rate of absorption, and individual susceptibility.

Air-borne substances include particulate matter such as dust, fume, mist, and fog of gases and vapors. Dust is composed of solid particles which do not tend to flocculate except under electrostatic forces and which do not diffuse in air, but settle under their gravitational influence. These particles are generated by grinding, crushing, impact, detonation, decrepitation, or other forms of energy resulting in attrition of either inorganic or organic materials such as rock, metal, wood, or grain. Fume is composed of solid particles which tend to aggregate and coalesce into clumps or chains. These particles are generated by condensation from the gaseous state such as

²John H. Foulger, "A Practical Approach to Protection of Laboratory Personnel from Toxic Materials," Journal of Chemical Education, XLII (April, 1965), A286.

from volatilization from molten metals and by some oxidation reactions. Mist is composed of small-sized suspended liquid droplets which are generated by condensation from the gaseous state to the liquid state such as by atomizing, by foaming, or by splashing. Fog is composed of large-size liquid particles of condensates.³ A gas is a state of matter which in actuality is quite formless and can be changed to the liquid or solid state by the combined effects of decreased temperature and increased pressure. The term vapor is used for the gaseous form of any matter which is in the liquid or solid state at ordinary conditions of temperature and pressure.

In the biologic aspects of particulate matter, smaller particles tend to be more injurious than larger particles because they remain suspended longer, more may be inhaled, and these are less easily removed from the lungs. Particles of high density act on the body in the same manner as larger particles of smaller density when passing down the respiratory tract because of their impact on walls of the upper respiratory tract due to greater mass and consequent inertia. Also slow, deep respirations tend to result in larger amounts of particulates deposited in the lungs. High physical activity increases the toxic effects, as a greater number of particles are inhaled to a greater depth and with an increased circulation rate, allowing amounts of chemicals to enter the body. Also, an elevated room temperature increases the toxic response of inhaled materials.⁴

Gases and vapors are absorbed and retained by the body in a different manner than the various particulate substances are. The depth to which a gas penetrates depends upon its solubility in the aqueous environment of the

³Stokinger, loc. cit.

⁴Ibid., A724.

respiratory tract. The amount of a gas or vapor absorbed into the blood stream depends on the nature of the substance, on the concentration in the inhaled air, and on the rate of elimination from the body. For any particular gas a limiting concentration in the blood is attained that is never exceeded regardless of the length of time it is inhaled if the concentration of the inhaled gas in the air remains constant.⁵

As gas, vapors and particulate substances can easily move from the place where they are produced, adequate ventilation is the simplest and most logical precaution. Preferably exhaust ventilation should remove the gases and particulates. Ventilation is not always adequate or of the proper type in high school laboratories, but for most laboratory experiences at the secondary level, substitution of less hazardous materials minimizes the needs for ventilation.

III. INGESTION

Ingestion. Ingestion is usually only from the most highly toxic substances. Some inhaled materials lodge in the upper respiratory tract, are swept up by ciliary action, and are swallowed. Those materials in the gastrointestinal tract do not readily pass into the blood as they are diluted in the food-liquid mixture, are acted on by the stomach acids and alkaline intestinal fluids, are absorbed selectively, and when absorbed into the blood most substances are metabolically altered, degraded, and detoxified by the liver.

Again, high school instructors need to stress personal cleanliness. Students must see the importance of thorough washing before eating in order

⁵Ibid., A721-A725.

to avoid unnecessary and accidental swallowing of any chemical, even though it may appear quite harmless.

Toxic chemicals produce their harmful effects by physical, by chemical or physiological means, or by a combination of these. With most chemicals the full toxic potential is not usually asserted because of destructive actions within the body and its mechanisms of elimination. Harmful chemicals which act physically on the body have a solvent or emulsifying action producing prolonged or repeated dermatitis, irritation, or inflammation. Those which act chemically produce injurious effects on the organs and tissues of the body either by depression or by stimulation of normally functioning pathways of metabolism.⁶

⁶Herbert E. Stokinger, "Mode of Action of Toxic Substances," Journal of Chemical Education, XLIV (October, 1967), A385.

CHAPTER IV

SAFETY INSTRUCTIONS WITH CHEMICAL REAGENTS

Safety with chemical reagents has several important aspects. Always there is the problem of storing the chemical reagents which must be purchased in preparation for the laboratory exercises. Some reagents may no longer be needed, have decomposed, or are waste products from laboratory exercises. Therefore, safe disposal is necessary. Another important aspect to consider is the prevention of reactions of incompatible chemicals, which might cause violent, explosive reactions or may cause ignition of nearby combustible materials. Reactions of this type may occur if these chemicals are not properly stored and come in contact with each other, if these chemicals are used in the same laboratory or at the same laboratory table, or if some student mixes reagents just to see what happens as many high school students have a tendency to do unless discouraged. It is always important to remember those chemicals which are hazardous so that necessary precautions may be made to lessen or avoid their effects or so that some other less dangerous reagent may be used in place of a hazardous one.

I. STORAGE

Storage. Storage of chemical reagents always requires special considerations. In many high school laboratories storage facilities are quite limited. There may be no separate supply room or preparation room, thereby leaving all chemical reagents and other apparatus to be stored in the classroom. If the high school building is small or if the school has a small enrollment, there may be just one science room in which one teacher is responsible for storage and supervision of all science equipment and

supplies. Then storage of chemical reagents becomes even more of a problem, as this generally means that many reagents, even though purchased in small quantities, will not be used as rapidly and must be stored over a longer period of time.

Storage of all chemical reagents should be in a separate storage area, in closed metal cabinets, and on acid-proof shelves. This should be in a cool, dry place away from direct sunlight or burner flames, yet protected from freezing. Since the fumes from reagents will inevitably be present, it is unwise to store any physics equipment or any metal apparatus in the same room.¹

Some chemicals should always be stored in small quantities. This includes those chemicals which are so sensitive to moisture or oxygen that deterioration begins when the seal of the bottle cap is broken as the container is opened for the first time, or those which react with the carbon dioxide in the atmosphere. This group of chemicals includes chlorides of phosphorus, silicon, aluminum, iron, titanium, tin, and the alkali metals, ammonium and alkali metal sulfides and cyanides. Also, chemical reagents of high purity should always be stored in small quantities, not over one hundred grams per container.² These containers should have a protective cap over the stopper.

Acids should be stored in a separate section of the storage area with special care given to the containers of concentrated acids. The acid bottles, especially those of the strong acids such as hydrochloric, sulfuric,

¹Alexander Joseph, et al., A Sourcebook for the Physical Sciences (New York: Harcourt, Brace and World, Inc., 1961), p. 606.

²H. A. J. Pieters and J. W. Greyhton, Safety in the Chemical Laboratory (New York: Academic Press, Inc., 1957), p. 240.

and nitric, weigh several pounds each. These should always be stored on low shelves so the use of a ladder is unnecessary to remove the bottle from the shelf or to lift a bottle above head height. Acid bottles must be protected against heat and sunlight because acids, especially nitric and sulfuric, decompose when warm. As decomposition takes place, released pressure may cause the containers to burst.³ This could cause other nearby containers to break, also. The outside of each bottle and its stopper should always be kept clean and dry.

In storing cylinders of compressed gases, always place the cylinders upright in a ventilated area away from heat or ignition sources. Never remove or deface the label identifying contents of the cylinder. Do not tamper with any part of a valve, such as the safety or packing nuts, and always remember to close valves of empty cylinders. When all the gas is used from a cylinder, mark the cylinder "empty", but do not attempt to refill a cylinder.⁴

Oxidizing agents should not be stored near combustible materials because of fire dangers. Also, oxidizing agents should be isolated from acids. Oxidizing agents include chlorates, perchlorates, bromates, nitrates, peroxides, permanganates, and chromium trioxide.

II. DISPOSAL

Disposal. Disposal of unused chemical reagents or of some dangerous chemical products presents a problem in most high school laboratories. Each

³Charles W. Bahne, Fire Protection for Chemicals (Boston: National Fire Protection Association International, 1956), p. 6.

⁴George Pinney, "Compressed Gas Cylinders and Cylinder Regulators Used in Laboratories," Journal of Chemical Education, XLII (December, 1965), A976-A980.

chemical has its own properties; therefore, disposal of each is an individual problem.

Chemical solutions poured into a sink which is not equipped with special plumbing of silicon steel drain pipes or of some other type of noncorrosive material is always poor practice. Both acids and strong bases are damaging to ordinary pipes and drains; however, even in sinks with noncorrosive plumbing the sinks and drains should be thoroughly flushed with running water after disposal of any chemical. Each chemical should be poured slowly into the drain while allowing much water to dilute it as disposal is made. Disposal of one chemical after another should be avoided because they may react together.⁵ Another precaution is to be careful that disposal of chemicals in the drain does not include any substance which gives off objectionable odors or toxic gases in the sewer system.⁶

Disposal should always be made of the contents of the containers from which the stopper cannot be removed, from which the chemical reagents are no longer needed, or from which labels have been lost or obliterated.⁷ Since powdered dry wastes may be inflammable or explosive, these should not be mixed with ordinary waste that is to be burned. Also, even though broken glassware is not a chemical reagent, disposal of this is necessary and a proper container, preferably one of stone or earthenware rather than metal, should be designated for such purposes.

Many times it is necessary to react a dangerous or toxic reagent with

⁵Joseph, op. cit., p. 613.

⁶Pieters, op. cit., p. 20.

⁷Joseph F. Voeglein, Jr., "Storage and Disposal of Dangerous Chemicals," Journal of Chemical Education, XLIII (February, 1966), p. A156.

another reagent to make it less toxic before disposal can be made safely. Peroxides should be reduced or halogen nitrogen compounds should be made basic by reacting with ammonia or oxides.⁸ A strong acid neutralized is much less damaging to the plumbing.

Objectionable odors and noxious materials may be produced in high school laboratory exercises. The chemistry students, as well as other members of the student body, need protection from these substances which can be removed by proper laboratory ventilation. Ideally each high school laboratory should have a laboratory fume hood as well as exhaust fans for general laboratory ventilation. For best disposal of vapors, gases, and particulates, the exhaust fan from a fume hood fan should be on the roof of the building. This location not only reduces noise in the laboratory but also assures that any leaks which may develop in the system will not allow contaminants to escape into the building. Material for hood exhaust ducts should be noncorrosive as well as chemical resistant and the exhaust fan should be of heavy duty equipment with corrosive-resistant impellors.⁹

If proper ventilating facilities are not available, a ventilation system can be prepared by using either a ceiling exhaust fan or a window exhaust fan which directs the objectionable vapors and odors from the room or from a metal enclosure leading more directly to the exhaust fan. To such a system there must be some open windows to allow air circulation through the room, through the enclosures, and out the exhaust fan.

⁸Pieters, op. cit., p. 31.

⁹Norman V. Steere, "Ventilation of Laboratory Operations, Part Two," Journal of Chemical Education, XLI (March, 1964), A183-A188.

Although cleaning up spilled acids is not truly disposal of chemical reagents, any spillage can create an emergency disposal situation. If a large container of acid is accidentally spilled, the room should be ventilated as quickly and as well as facilities allow, because some acids, such as nitric and hydrochloric, release toxic gases. Protect the skin and clothing as much as possible while neutralizing or cleaning up the spilled acid to prevent skin burns. If, however, acid should be on the skin, flush with running water to dilute the acid in order to prevent deep acid burns, then wash thoroughly with limewater, baking soda solution or soap. If acid has splashed into the eyes, wash as quickly as possible with water and then with limewater.

If the acid is spilled in the chemical storeroom, it is best to use as little water as possible in cleaning up the acid. A small amount of water may cause heating and violent spattering of water-reactive chemicals which may be present, such as calcium oxide or sodium hydroxide. It is best to use a neutralizing absorbent mixture, such as sodium carbonate, soda ash, and diatomaceous earth or sodium hydrogen carbonate, (baking soda) to neutralize the acid first before soaking up the liquid. Sawdust or paper should not be used to absorb the remaining liquid in a nitric acid spill, as any nitric acid may nitrate the sawdust or paper enough to cause it to become explosive. This would have a very low kindling temperature so that it would be very combustible. Hydrochloric acid or sulfuric acid spills may be absorbed by sawdust or paper after neutralizing with soda ash or baking soda. If paper or sawdust is used to absorb the acid before neutralizing, be sure to scoop up this material, soak with water, and do not burn in an incinerator. If no neutralizer or water is available, dirt, sand, or talc may be

poured in the spilled acid until other cleaning-up procedures can be taken.¹⁰

III. CHEMICAL REAGENTS

Acetates. Inorganic acetate compounds are soluble in water and are readily decomposed by strong acids or heat. Organic acetates are flammable.

Acetic acid. Glacial acetic acid causes irritation to the skin and to the mucous membranes of the mouth and upper respiratory tract; it dissolves the blood corpuscles and affects the kidneys. This acid is incompatible with nitric acid, chromic acid, any hydroxyl compound, ethylene glycol, peroxides, such as hydrogen peroxide and sodium peroxide, and permanganates, such as potassium permanganate.

Acetone. Acetone is combustible and its vapors explode easily; therefore, containers should never be filled completely, exposed to sunlight, or stored in a warm place. Inhalation of vapors irritates mucous membranes and causes headaches, fainting and general poisoning.

Alcohols. Alcohols have a narcotic action on the body. Methyl alcohol, methanol, is extremely toxic in small doses if inhaled. It may be absorbed through the skin and lungs and may cause blindness due to damage of the optic nerve or degeneration of the kidneys as the body tries to remove it. Ethyl alcohol, ethanol, causes such poisonous compounds as aniline, calcium cyanamide, nitrobenzene or halogenated hydrocarbons to have a more toxic effect.

Alkali metals. Alkali metals are the elements of Group IA, which

¹⁰Bahme, op. cit., pp. 6-8.

includes lithium, sodium, potassium, rubidium, and cesium. Since all light metals are readily flammable at relatively low temperatures and ignite explosively when moist, these metals should be stored in small quantities under kerosene. All alkali metals decompose in water violently to yield hydrogen. Fumes which are given off upon hydrolyzing in the air cause irritation to the nose, throat, and skin. Burns are produced when any one of these metals come in contact with the skin. These skin burns should be washed thoroughly in running water before neutralization with dilute acetic acid or vinegar. All alkali and alkaline metals are good reducing agents. Alkali metals should be kept away from carbon tetrachloride and carbon dioxide as well as water because of the possible explosive reactions.

Aluminum. Aluminum should be stored separately from oxidizing materials, alkaline caustic solutions, acids, halogens, or flammable materials because it is a good reducing agent. Powdered aluminum reacts explosively with an oxidizing agent, such as chlorate or nitrate compound, or with carbon tetrachloride, carbon dioxide, or any halogen. With a halogen, spontaneous ignition may be caused; with water, acids, or alkaline solutions, hydrogen may be generated.

Ammonia. Anhydrous ammonia reacts dangerously with mercury, halogens, such as chlorine, bromine, or iodine, or such compounds as calcium hypochlorite or anhydrous hydrofluoric acid. Liquid ammonia and mercury form a very explosive compound. Before disposal of ammonia in a drain, it should be neutralized with an acid.

Ammonia Compounds. Ammonia compounds have quite contrasting properties; therefore, it is important to consider each compound separately. Those

ammonium compounds which are explosive and are susceptible to detonation by varying degrees of shock or sometimes by heat include ammonium bromate, chromate, chlorate, dichromate, nitrate, nitrite, perchlorate, permanganate, persulfate, and picrate. Some of these give off toxic gases when heated. Ammonium dichromate is flammable and is a skin irritant, whereas ammonium hydroxide is nonflammable and relatively nonhazardous. A particularly unstable compound is ammonium nitrite.

Antimony. Antimony metal is tasteless, odorless, and nontoxic but when heated volatilization in air occurs and forms toxic and irritating antimony oxides. The soluble antimony compounds are almost as poisonous as arsenic. Antimony or any of its compounds react with acids and antimony ignites chlorine gas spontaneously.

Arsenic. Arsenic and all its compounds are poisonous and affect all systems of the body; however, very small amounts of many arsenic compounds have medicinal values.

Barium. All water and acid soluble compounds of barium are poisonous.

Benzene. Benzene is a highly toxic substance which gives no warning to an individual exposed to it. Its faint odor is not disagreeable or irritating but it may be inhaled or absorbed through the skin, causing damage to many parts of the body and with a definite narcotic action on the body. It is a very flammable liquid which is used as an organic solvent.

Benzoyl peroxide. Both benzoyl peroxide and acetyl peroxide, strong organic oxidizing agents, are highly flammable and extremely explosive as decomposition may take place instantaneously; therefore, these should be

stored away from other combustible materials and inorganic oxidizing agents.

Beryllium. Beryllium and all its compounds are exceedingly poisonous.

Bromine. Liquid bromine is caustic to the skin and inflicts deep, painful burns. Bromine vapor is extremely irritating to the skin, mucous membranes, eyes, and respiratory organs. Bromine causes fires when in contact with combustible materials, such as wood, excelsior, or sawdust. Bromine reacts violently with hydrogen, either aqueous or anhydrous ammonia, acetylene, finely divided metals, sodium carbide, or lighter molecular-weight alkanes, such as methane, ethane, propane, butane, or any other petroleum gas.

Bromides. Most bromides are nonhazardous and most inorganic bromides are soluble in water.

Cadmium. Cadmium dust has low flammability. Cadmium and its soluble compounds resemble arsenic or mercury in poisonous reactions to the body.

Calcium. Calcium should be kept dry, as it reacts with water to produce hydrogen gas. Calcium reacts explosively with carbon tetrachloride, carbon dioxide, or any halogen. Calcium carbide is nonflammable, but reacts with water to produce the flammable gas acetylene, therefore, should not be stored near combustible materials. Calcium hypochlorite is not a combustible compound, but when it is heated, it liberates oxygen to support combustion. When it is exposed to the air or water, chlorine gas is released. Spontaneous ignition may result if calcium hypochlorite is in contact with organic materials or flammable liquids. Also it reacts violently with activated charcoal.

Carbides. The carbides of some metals, such as sodium and potassium react explosively with water. Some carbides, such as carbides of lithium, potassium, calcium, strontium, or barium, decompose in water to produce acetylene gas. Copper or silver carbide do not produce acetylene with water but are explosive with heating or jarring.

Carbon. Activated charcoal is more dangerous than other forms of carbon, as it reacts explosively with calcium hypochlorite or any other oxidizing agent even in the dry state. It should not come in contact with chlorine, oil, or other hydrocarbon, because of the danger of spontaneous ignition. Charcoal, such as graphite, animal charcoal, or wood charcoal, which are normally quite nonflammable are more susceptible to spontaneous ignition upon subsequent drying after being wetted as they have a greater tendency to heat spontaneously.

Carbon monoxide. Carbon monoxide, a colorless, odorless, tasteless combustion product of any carbon compound, is a poisonous gas which combines readily with the hemoglobin in the red blood corpuscles and causes them to lose their oxygen-carrying capacity. The deficiency of oxygen to the body cells causes headache, dizziness, and general weakness, affecting both the nervous system and the circulatory system. The red blood cells burst and internal hemorrhages may be caused as the blood vessels and capillaries break. Severe, acute intoxications with carbon monoxide produce unconsciousness and death.

Carbon disulfide. Carbon disulfide, a compound with an offensive odor, has an ignition temperature so low that its vapor can be ignited from a steam pipe or a light bulb. It has a low flash point and a wide explosive

range; its vapor may be exploded by a sudden blow to its container. When mixed with air, carbon disulfide vapor burns explosively. Not only are the vapors poisonous but also the products of combustion, which include sulfur dioxide and carbon monoxide, are toxic. Carbon disulfide is immiscible with water and is inert to most metals, ceramics, glass, and steel. It is extremely toxic, affecting practically all parts of the nervous system. It may be inhaled and absorbed into the blood from the lungs or may permeate the skin. It has narcotic properties as it dissolves fat tissue, and causes headaches, irritability, slow breathing, and muscular weakness. This solvent is so dangerous that its use should be avoided whenever possible.

Carbon tetrachloride. Carbon tetrachloride, a colorless liquid with a peculiar odor and vapors heavier than air, is nonflammable. It may be used as a fire extinguisher or as an organic solvent for fats and oils. In the presence of a flame or hot metal, especially aluminum powder, carbon tetrachloride is partially converted into phosgene, a highly toxic war gas. Carbon tetrachloride should never be used on a fire involving alkali or alkaline earth metals, because of the danger of explosive reactions. Carbon tetrachloride vapors are extremely toxic, causing nausea, vomiting, headache, dizziness, palor, weak pulse, subnormal temperature, and general effects on the digestive system.

Chlorates. Most chlorate compounds are soluble in water and liberate oxygen with heating or jarring. These compounds are strong oxidizing agents and produce flammable mixtures with any organic material such as boric acid or borax. All chlorates should be kept away from sulfuric acid or other strong acids because chlorine gas and the explosive chlorine peroxide gas may cause a fire. Spontaneous decomposition and ignition occur when

chlorates are mixed with ammonium salts. Any chlorate or perchlorate should not come in contact with metal powders, phosphorus, sulfur, or sulfides, especially antimony sulfide, because the reaction products are extremely sensitive to friction.

Chlorides. Most inorganic chlorides are nonhazardous, but some organic chlorides such as ethyl chloride or vinyl chloride are extremely flammable.

Chlorine. When chlorine is inhaled in small quantities, it affects the mucous membranes of the nose and throat, producing about the same symptoms as a bad head cold. If chlorine is inhaled in larger quantities, it is so toxic that it causes death. The effects from breathing chlorine are partly alleviated by inhaling either alcohol vapors or ammonia. Although nonflammable, chlorine is capable of supporting combustion of certain substances, such as sodium, potassium, phosphorus, and antimony. Chlorine also reacts with sodium carbide and finely divided metals forming spontaneously flammable compounds. When combined with oxygen or oxides, chlorates may be formed; some of these are explosive. Also, when chlorine is in contact with hydrogen, either aqueous or anhydrous ammonia, acetylene, or low molecular-weight alkanes, such as methane, ethane, propane, or butane, explosive reactions occur. Cylinders of chlorine gas should always be stored in their original containers, receiving the same care given to any cylinder of compressed gas. If a leak occurs, chlorine may be absorbed in solutions of an alkali hydroxide or carbonate or in calcium hydroxide.

Chromates. Most chromates, such as sodium chromate or potassium chromate, are good oxidizing agents, but are not readily flammable; however, when heated with sulfuric acid, organic matter may be ignited. The skin is

is very sensitive to chromate compounds.

Chromic acid. Chromic acid reacts dangerously with acetic acid, naphthalene, camphor, glycerol, flammable liquids, such as alcohols and ethers, and turpentine. This acid should be stored in stainless steel or glass containers protected by stainless steel jackets and covered by a stainless steel lid, as it is flammable and explosive. The skin and mucous membranes of the nose and throat are irritated by chromic acid. Both chromic acid and chromate compounds interfere with cell metabolism and can cause damage to the kidneys as well as to the respiratory organs.

Citrates. Generally all citrate compounds are nonhazardous.

Copper. Copper is not toxic in the metallic state, but all soluble copper compounds, especially copper (II) acetate and copper (II) sulfate, are poisonous. The toxic effects are on the respiratory, circulatory, and digestive systems. Copper powder, as well as powders of cadmium, chromium, and lead, are slightly flammable but cannot be considered explosive. Copper and its compounds react with peroxides, especially hydrogen peroxide, and with acetylene, ethers, or ammonia to produce explosive compounds. Copper reacts with hot concentrated sulfuric acid to produce the poisonous sulfur dioxide gas and with concentrated nitric acid to produce the poisonous nitrogen dioxide gas.

Cyanide. Any solutions containing the cyanide ion are deadly poisons and should never be handled by inexperienced students.

Formaldehyde and formalin. The vapors of formaldehyde and formalin act chiefly on the upper respiratory system.

Glycerol. Glycerol should not come in contact with any permanganate compound because of the danger of a violent reaction that may cause a fire.

Halogens. Halogens, nonmetallic elements of Group VII including fluorine, chlorine, bromine, iodine and astatine, are quite reactive and should be used carefully. Flourine gas is so violently reactive that everything should be kept away from it. The other halogens, except for astatine, a radioactive element, are discussed separately.

Hydrocarbons. The light hydrocarbons have a narcotic effect on the body and exposure to these irritates the skin and mucous membranes. With longer exposures nervous system disturbances are caused. Hydrocarbon compounds, such as alkanes, benzene, turpentine, or gasoline mixtures, react violently with sodium peroxide, chromic acid, and the halogens. When preparing hydrocarbons in laboratory exercises, do not collect in any container which holds more than two hundred fifty milliliters because of the danger of explosive mixture with air.

Hydrochloric acid. Gaseous hydrogen chloride is a primary irritant and produces a destructive action on the membranes of the upper respiratory tract. The acid produces severe skin burns and its vapors should not be inhaled. Remove the cap from the acid bottle carefully to avoid spouting. It is a strong acid which needs careful storage as do all strong acids.

Hydrogen peroxide. Concentrated solutions of hydrogen peroxide causes burns which should be treated with hot water, or with a sodium thiosulfate solution. Hydrogen peroxide solutions are not flammable, but as a strong oxidizing agent, it may cause the ignition of combustible material with which it is in contact. More concentrated solutions of hydrogen peroxide should

be kept away from almost every metal, especially magnesium, zinc, aluminum, iron, copper, and chromium, or metallic salt, flammable liquids, such as alcohol or acetone, or combustible material. With alcohols, hydrogen peroxide forms powerful explosives which can be detonated by shock. Since the compound is extremely unstable, hydrogen peroxide solutions decompose into oxygen and water when warm. For this reason a fresh supply should be purchased each year.

Hydrogen sulfide. Hydrogen sulfide is a very dangerous gas, ranking with hydrogen cyanide in its poisonous properties. Although low concentrations have a very disagreeable odor, that of rotten eggs, after a relatively short exposure or in higher concentrations the sense of smell rapidly becomes atrophied. When diluted with air, it causes nausea, headache, and dizziness. Hydrogen sulfide is used extensively in qualitative analysis, since it forms characteristic colored sulfides by which a mixture containing unknown metals may be identified. Since it is so poisonous, its use should be avoided as much as possible. In many of the qualitative tests, ammonium sulfide, a nonpoisonous compound, may be substituted with good results. It should not come in contact with any oxidizing gases or concentrated nitric acid because of explosive reactions.

Hydroxides. The common hydroxides, sodium hydroxide, potassium hydroxide, and ammonium hydroxide, are soluble in water. They are not combustible but react with water to generate heat; they must, therefore, be stored away from moisture and combustible substances. Solutions of these strong hydroxides react with zinc, galvanized metals, or aluminum with the generation of hydrogen; a hydrogen explosion may result if a source of ignition is present. Hydroxides should be kept away from acids, explosives, such as nitrate

compounds, and trichlorethylene. The term caustic alkali is used for these strong soluble hydroxides, sodium hydroxide and potassium hydroxide, because they severely burn and destroy human tissue. If any hydroxide solution is splashed on the skin, wash thoroughly with running water, then wash with dilute acetic acid or vinegar. Other hydroxides, such as calcium hydroxide or magnesium hydroxide, are relatively weak.

Iodine. Iodine is usually in the form of purple-black crystals which are quite volatile. The vapors are poisonous and corrosive. It affects the respiratory system, digestive system, and nervous system. It is insoluble in water and should not come in contact with the skin. Iodine will explode spontaneously when diffused with ammonia and is also explosive with acetone, turpentine, or hydrogen.

Iron. Iron is not poisonous, but iron powders are combustible just as any other finely divided metal is when dispersed in the air with suitable sources of ignition present.

Lead. Lead and most lead compounds are very toxic. Absorption into the body may be through the skin or through inhalation of dusts. Lead compounds are more soluble in blood than in water. The accumulative effects of lead damage the blood vessels, heart, kidneys, and nervous system.

Magnesium. Magnesium or magnesium compounds are not poisonous. At high temperatures magnesium reacts violently with water, liberating hydrogen, and with carbon dioxide, liberating carbon. Magnesium powder reacts explosively with carbon tetrachloride, any halogen, chlorate, nitrate, phosphate, sulfate, carbonate, or with many oxides. Skin burns resulting from these reactions may be quite deep and painful.

Manganese. Dusts and fumes from many manganese compounds, including manganese dioxide, are poisonous, but inhalation from these is usually found only in special industries.

Mercury. Mercury and many of its compounds are very toxic. Mercury can enter the body in many ways; by the digestive system, by the respiratory system being inhaled as vapor or mist, or by the skin, especially if there is a break in the skin. Soluble mercury compounds produce severe, acute poisoning. Inhalation of small concentrations of mercury vapor, either regularly or periodically over a long time, has cumulative toxic effects on the digestive system and kidneys. Since mercury is so dangerous, any work with mercury in open vessels should be avoided. An inexperienced person should never try to purify mercury. In using any apparatus which requires mercury, place the apparatus under an exhaust hood and in a wooden tray, an enameled tray, or a shallow tray containing water. Never use an aluminum tray because of serious corrosion. If any mercury should accidentally be spilled, it may be removed by freezing with dry ice and sweeping, rubbing the area with tin foil or amalgamated copper. Flowers of sulfur or calcium polysulfide placed on spilled mercury droplets cause a harmless reaction product of mercurous sulfide. Evaporation of mercury at room temperatures can be minimized by covering with water; however, it is best not to use mercury as a sealing liquid, especially in a hot place. Mercury should not come in contact with acetylene, anhydrous ammonia, or oxalic acid because of possible explosive reactions.

Nickel. Nickel and nickel compounds are somewhat less dangerous than copper salts, but are still poisonous.

Nitrates. Nitrate compounds are quite unstable because of their low negative heats of formation. All inorganic nitrate compounds are good oxidizing agents, evolving oxygen when heated. These compounds should not come in contact with an ester or stannous chloride because of the explosive reaction. Ammonium nitrate has a tendency to absorb moisture so it should be stored in small quantities and as dry as possible. Ammonium nitrate reacts explosively with zinc powder and a drop of water. Ammonium nitrate should be kept away from acids, flammable liquids, sulfur, chlorate compounds, or any finely divided organic or combustible substance as well as metal powders. Potassium nitrate also reacts explosively with sodium acetate.

Nitrides. Nitrides are noncombustible; some are decomposed by water yielding ammonia and a few, especially silver nitride, may be detonated by heat.

Nitrites. Nitrite compounds should be stored and handled like nitrate compounds. Inorganic nitrites are less active oxidizing agents than nitrates but these increase the combustibility of materials. Some nitrites, such as ammonium nitrite and methyl nitrite, are explosive with heat. Sodium nitrite when mixed with any ammonium salt decomposes spontaneously with the liberation of heat.

Nitric acid. Concentrated nitric acid etches the skin; however, with time the yellow stain due to reaction with albumens disappears. The vapor from nitric acid is a serious respiratory poison. Since nitric acid is a very good oxidizing agent, care must be taken in reactions with any combustible material in order to prevent fire or explosion. Fulminates,

highly explosive compounds with a positive heat of formation, may form when traces of an organic substance react with nitric acid and mercury. Mixtures of sulfuric acid and nitric acid may be dangerous because of possible explosions. Concentrated nitric acid should not come in contact with acetic acid, chromic acid, or flammable liquids, such as alcohols or ethers, or flammable gases, such as hydrogen sulfide. This acid also reacts explosively with hydrogen iodide and with such metals as zinc and magnesium, as well as such nonmetals as phosphorus.

Nitrogen. Nitrogen is a relatively inactive gas under normal atmospheric conditions. It does not burn in oxygen; however, oxides may be formed from various reactions as well as by an electric arc. At high temperatures nitrogen combines with such metals as magnesium, titanium, and aluminum to form nitrides.

Nitrogen oxides. Any atmosphere in which nitrogen oxides can be detected by the odor should be considered dangerous. Of the various gaseous nitrogen oxides, most of which are colorless and nontoxic, nitrogen dioxide is the only poisonous gas which indicates its presence by color: brown. The reaction of nitrogen oxides with moisture causes nitrous and nitric acid to be formed in the mucous membranes of the respiratory tract, producing a burning sensation and coughing. It also affects the red blood cells, heart, liver, and kidneys.

Oxalic acid. Oxalic acid reacts readily with metals below hydrogen on the replacement series, such as mercury and silver.

Oxides. Nonmetallic oxides react with water to form acids, whereas soluble metallic oxides react with water to form bases. Some of these react

vigorously with the evolution of considerable heat so that combustible materials may ignite.

Peroxides. Generally inorganic peroxides decompose easily with heat or water to produce oxygen. Since all peroxides are strong oxidizing agents, these should not be stored with readily flammable materials, such as charcoal, sulfur, metal powders, or with acids or organic peroxides. Always store the container of sodium peroxide or barium peroxide in sealed containers. These should be purchased in small quantities. Hydrogen peroxide is discussed separately.

Permanganates. All permanganate compounds are strong oxidizing agents and are subject to ignition by friction. Also, they may ignite spontaneously if acted on by an acid. Potassium permanganate is spontaneously flammable and reacts violently with glycerol, ethylene glycol, sulfuric acid, or formaldehyde. It should not come in contact with charcoal or sulfur because of possible explosive reactions.

Phosphorus. Phosphorus is usually stored in the high school chemical reagents in both red and white (yellow) allotropic forms. Since white phosphorus has such a low kindling temperature, it should be stored isolated from oxidizing agents, flammable liquids, and explosives and kept in a glass container which is completely filled with water and closed with a ground glass stopper. This container should be placed in a metal storage container which also contains water. With the storage of white phosphorus, certain gaseous products are formed, acidifying the water covering the phosphorus. Solubility of phosphorus makes it necessary to change the water in which the phosphorus is stored. Care must be used that these phosphorus sticks are

not touched by the hands or left out of water. The safe limit for the water in the phosphorus container may have a pH between five and nine. Red phosphorus does not need to be kept under water but it should be kept away from oxidizing agents and should be kept as dry as possible, because it may revert to white phosphorus on condensation. In so doing it takes on the toxicity and fire hazard characteristics of white phosphorus. White phosphorus is very toxic causing degeneration of bones, muscles, liver, and internal bleeding, but red phosphorus is not toxic. Phosphorus oxides have pungent, suffocating odors.

Potassium. Potassium is a very active, light metal of Group IA, the alkali metals, with characteristic properties of these chemical elements.

Silver. Silver reacts violently with acetylene, oxalic acid, tartaric acid, and ammonium compounds and reacts readily with oxidizing agents such as nitric acid and hot concentrated sulfuric acid. It undergoes no chemical reaction in water or pure air or with hydrochloric acid, fused sodium hydroxide. It tarnishes in the vapors of sulfur compounds but this is neither a violent nor a poisonous reaction.

Sodium. Sodium is a very active alkali metal of Group IA and has properties characteristic of all Group IA elements.

Strontium. Strontium resembles calcium in its properties. Strontium salts are generally soluble except for sulfates, phosphates, and carbonates.

Sulfates. Inorganic sulfate compounds are noncombustible; however, many organic sulfates, such as dimethyl sulfate, release flammable toxic vapors at elevated temperatures.

Sulfides. Inorganic sulfide compounds, such as sodium sulfide, are moderately flammable. Many of these spontaneously ignite, especially if damp, when in contact with oxidizing agents. As inorganic sulfides burn, sulfur dioxide is produced. If water is added to inorganic sulfides, hydrogen sulfide gas is produced. Since hydrogen sulfide or sulfur dioxide may be produced, skin contact or inhalation of any sulfide should be avoided.

Sulfur. Sulfur is a yellow, odorless solid which burns with a pale blue flame in air to produce the toxic sulfur dioxide gas. Sulfur should not come in contact with ammonium nitrate or any chlorate because of possible explosive reactions.

Sulfur dioxide. Sulfur dioxide, a combustion product of sulfur, having a sharp, biting odor, is a primary irritant to the respiratory system and the eyes. In relatively high concentrations it is suffocating. Be sure to allow good ventilation whenever this gas is a reaction product. High schools do not need to store any cylinders of this gas.

Sulfuric acid. Fumes and mists from sulfuric acid severely irritate the respiratory tract. Skin burns from sulfuric acid are usually deep and produce scars. Concentrated sulfuric acid should not come in contact with organic substances, nitrates, sulfides, chlorates, perchlorates, halogenides, carbides, or many metals. These cause violent, explosive reactions. Dilute sulfuric acid should not come in contact with any light metal, such as potassium, sodium, or lithium, or any oxidizing agent, such as potassium permanganate.

Tartarate. Most tartarate compounds are not hazardous, with the exceptions of silver tartarate and mercury tartarate which are sensitive

explosives that may be detonated at relatively low temperatures.

Tin. Tin and tin salts are relatively harmless.

Toluene. Toluene is less toxic than benzene; however, inhalation of toluene causes headaches and may cause convulsions and loss of consciousness.

Zinc. Zinc and all soluble zinc salts are poisonous. Acid foods should never be stored in galvanized iron containers as zinc reacts readily with acids. Zinc also reacts violently with sodium hydroxide or potassium hydroxide.

IV. EMERGENCY FIRST AID

Although it is always best to call a doctor as quickly as possible when an accident occurs, there are some general measures that should be followed. The initial procedures followed in an emergency often determine the outcome of an accident, both to the student and to the facilities. All persons who have been severely burned, those who have swallowed poisonous substances, or those who have lost much blood suffer from some degree of shock; this should be treated first.

Treatment of shock. Presence of shock is indicated by the person feeling faint, being thirsty, or vomiting. Also the skin is cold and clammy, face is pale, pulse is rapid, and breathing is weak. Have the person lie flat, with the feet raised and the clothing loosened at the neck. Keep the patient warm and quiet. Liquids, such as warm tea or water, may be given if the person is conscious, but do not force liquids into an unconscious person. If breathing is feeble or has ceased, artificial respiration or oxygen may be administered.

Minor cuts and wounds. Cleanse the cut or wound thoroughly, using plain soap and warm running water. If the wound has been inflicted from broken glass, try to check that no splinter of glass is in the open cut. After washing, apply a sterile dressing.

Wounds with severe bleeding. Severe bleeding from a vein or artery requires immediate medical treatment; however, until medical treatment can be obtained, apply pressure directly over the severed blood vessel with a cloth or apply a tourniquet between the severed blood vessel and the heart. Treatment for shock should be given.

Heat burns. Skin burns caused by heat or by chemicals may be classified according to depth or degree; first degree, skin reddened and swollen; second degree, blisters form; third degree, deep destruction as underlying cells are destroyed with the skin appearing brown, black, or sometimes white. The degree of burning is of less importance than the total area of the burn.

Treat first degree burns by flushing with cold water until all sensations of burning and pain have ceased.

Treat second degree burns by applying a dry sterile dressing to prevent the blisters from opening or if the blisters do break, they will be exposed to the sterile dressing.

Treat third degree burns by applying a sterile dressing to prevent the burned skin from being rubbed off and the burned area from being injured. Get medical treatment as soon as possible.

Chemical burns. Chemical burns may be from either acids or alkalis. With either, wash as quickly as possible with large quantities of running water. Acid burns may then be treated by using soap, by using mixtures of

baking soda and soap suds, or by using limewater. Alkali burns may be neutralized with weak vinegar, hard cider, or lemon juice.

Eye contamination. Unless absolutely sure what type of chemical, acid or alkali, splashed into the eye, hold eyelid and wash eye with a gentle stream of running water only. If an acid is in the eye, wash as quickly as possible with water, then limewater may be used to wash the eye. If an alkali is in the eye, wash with a weak vinegar solution, with olive oil, or a saturated solution of boric acid after thoroughly washing with running water.

Inhaled poisons. If a poisonous chemical has been inhaled, carry the person to fresh air immediately. Loosen any tight clothing and keep the person warm and quiet. If breathing has stopped or is irregular, administer artificial respiration. Call medical help.

Swallowed poisons. In any case of oral poisoning, it is more important to dilute the toxic substance than to administer an antidote. It is dangerous to induce vomiting if the person is in a coma or is unconscious, is in convulsions, has swallowed petroleum products, such as kerosene or gasoline, or a corrosive chemical, such as an acid or acid salt, or an alkali or basic salt. Give milk, water, milk of magnesia, or limewater to a conscious person who has swallowed an acid; however, never give those persons any carbonates or bicarbonates. For an alkali, give the person milk, water, any fruit juice, or vinegar. Keep the person warm until medical help is available.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Safety in using chemicals is a very important phase of the high school learning experience. This perhaps is of more direct concern to the high school science instructors than to students as they are guided through various laboratory exercises. Since chemical safety includes not only knowledge of chemical reagents and chemical reactions, but also the effect these have on life and property, it is very important that a science instructor be aware of any substance or reaction which might cause injuries due to fires, explosions or toxic conditions.

Not always are chemicals harmful; but those that are toxic can enter the body by quite simple, yet many times, quite unnoticed routes, including absorption through the skin, inhalation, or swallowing. A knowledge of proper procedures for storing, transporting, and disposing of all chemicals is important in preventing accidents involving both individuals and physical facilities. It is especially important to have knowledge of any dangerous chemical reaction which might occur and which could be avoided if proper planning is made before any laboratory exercise. In avoiding contact of any incompatible combination of chemicals, it is also possible to prevent many accidents and injuries.

Chemical elements and chemical compounds form the central, most important phase of any learning experience in chemistry. Respect of individual chemical reagents must be stressed, but fear of all reagents does not need to be instilled in the students. Each time a chemical is used, it is not necessary for an instructor to discuss all its storage problems, incompatible chemical contacts or toxic effects on the body, but it is important for an instructor

to know of these in order that proper precautions can be made.

In this study of high school laboratory experiments taught by either the traditional or modern approach, it is quite evident that it is unnecessary to perform many dangerous chemical reactions or to use many toxic chemicals in teaching basic chemistry procedures and principles. Substitutions in the reactions or in the chemical reagents may be made for some of those experiments that are dangerous or involve toxic substances.

Knowledge of various aspects of safety with chemical reagents is of little value unless an instructor applies this knowledge as well as stresses cleanliness and orderly procedures in the laboratory learning experiences. Only then can many unnecessary accidents and injuries be prevented. "Chemical safety is as wide as the science of chemistry and sociology, and will become of increasing importance as both science and our civilization become even more complex."¹

¹Howard H. Fawcett, "The Literature of Chemical Safety-Part 1," Journal of Chemical Education, XLII (October, 1965), A816.

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A HANDBOOK FOR SAFETY WITH CHEMICAL REAGENTS

by

MERRIDY MYRTH KING

B. S., Marymount College, 1959

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An important aspect of safety in the high school laboratory is prevention of accidents when using chemical reagents. The purpose of this study was to develop a handbook for safety with chemical reagents. In the review of related literature from the Kansas State University library, from an inquiry to Educational Resources Information Center (ERIC) and to the Science Consultant from the Kansas Department of Public Instruction, and from a study of laboratory manuals for traditional and modern approaches to high school chemistry, many aspects of safety were noted with special emphasis on safety with chemical reagents. This included safety in regard to prevention of fire from chemical reagents, toxic effects from chemicals, or hazardous chemicals which may cause injuries to students or damage facilities.

In the study of safety with chemical reagents, the main areas studied included the physiological effects which chemical reagents have on the body, the correct methods for storage of chemical reagents and disposal of chemical reaction products, chemicals which are incompatible and must not come in contact with certain other chemicals because of possible fires or explosions, and those chemicals which are commonly used but are hazardous.

The physiological effects which chemicals have on an individual include any change in the functioning of a body organ or organ system as a result of exposure to a toxic chemical reagent. These reagents cause harm by gaining entrance to the body through skin contact, the most common entry route, through inhalation of particles or of gases and vapors, or through ingestion. These cause harmful effects by physical, by chemical or physiological means, or by a combination of both.

Storage of all chemical reagents should be in a cool, dry, dark, fire-resistant room. Oxidizing agents should not be stored in the presence of

combustible substances as these are potential fire hazards. Fires with oxidizing agents other than peroxide compounds can be extinguished with water but sand should be used on peroxide fires. Acids should be stored in a separate area; this should be away from oxidizing agents, metals and basic compounds. The very active alkali metals should be stored under kerosene so there is no chance for moisture to cause chemical reactions, but white phosphorus should be stored under water because of its low kindling temperature. Unstable compounds or compounds of high purity should be stored in small quantities. Containers of compressed gases should always be stored in an upright position in an area where there is adequate ventilation. Any gas which supports combustion should not be stored near any combustible gas.

Proper disposal is as important for many chemical products as proper storage is for many chemical reagents. Concentrated acid or basic solutions should be diluted before disposal in the sewer system. Chemicals which release toxic or objectionable gases should not be disposed of in the sewer. Adequate ventilation, either by fume hoods or ceiling or window exhaust fans or both, aid in removing objectionable and toxic gases and vapors from the laboratory. Cleaning up spilled reagents, especially of strong acids or bases, present emergency disposal situations.

Proper storage, proper disposal, and keeping incompatible chemicals from contact with each other prevent many accidents which might be caused by explosions or fire.